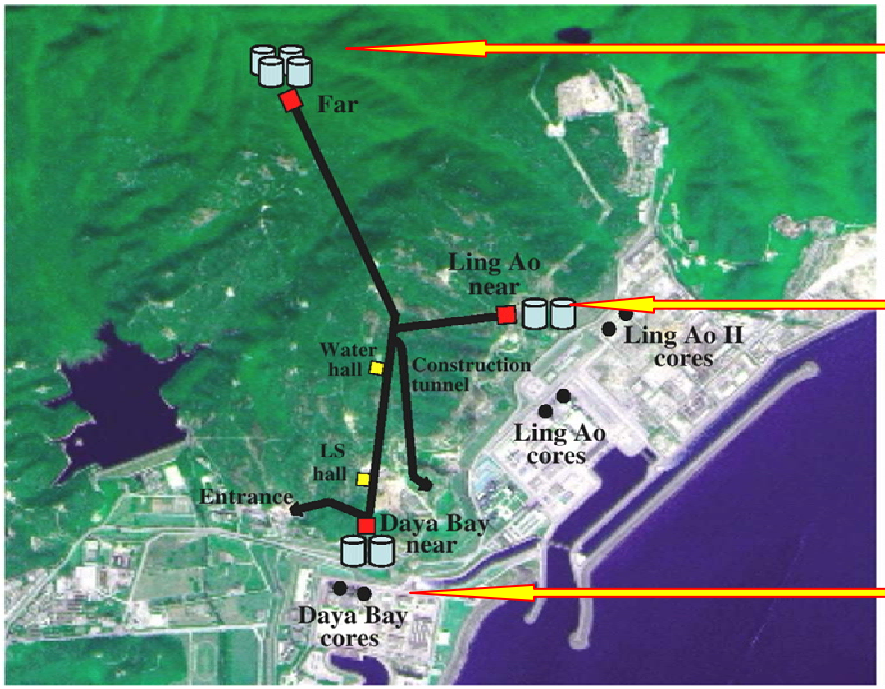
Muon Veto System and Expected Backgrounds at Dayabay

Hongshan (Kevin) Zhang, BNL
DayaBay Collaboration

DNP08, Oakland

DayaBay Experiment

The goal of the DayaBay neutrino reactor experiment: sensitivity of $\theta_{13} < 0.01$ at 90%CL.



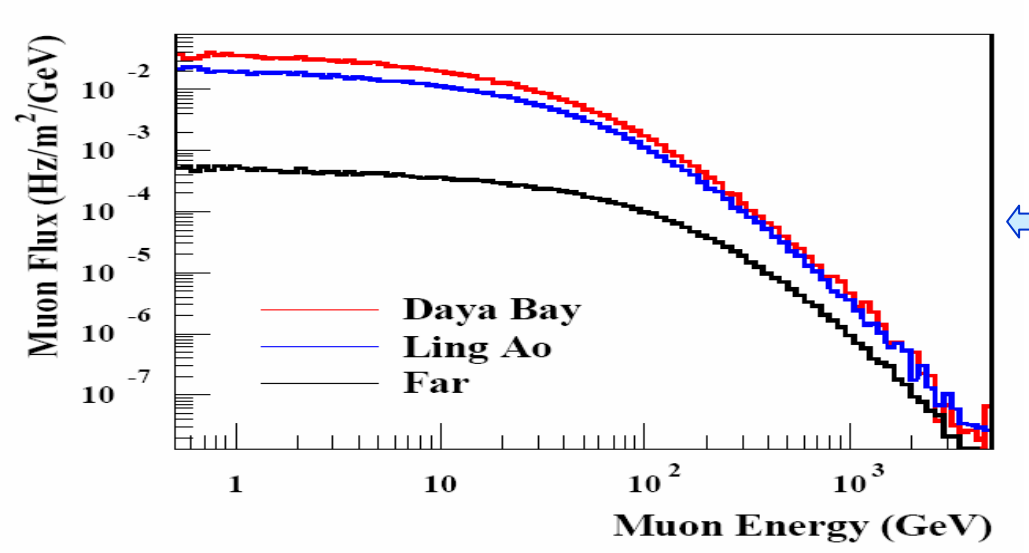
Far Site:
- 4 x 20 ton detector modules
- 1985 m from Daya Bay cores
- 1615 m from Ling Ao cores
- Overburden: 355 m

Ling Ao near site:
-~500 m from Ling Ao cores
-currently 2 x 2.9 GW reactor cores
- additional 2 x 2.9 GW cores by 2011
- 2 x 20 ton detector modules
- Overburden: 112m

Daya Bay near site:
- 363m from Dayabay cores
- 2 x 2.9 GW reactor cores
- 2 x 20 ton detector modules
- Overburden: 98m

Cosmic Muons in DayaBay

Detailed topo map, modified Gaisser formula, and MUSIC



⇦ **Expected Muon Flux from Simulation.**

	DYB site	LA site	Far site
Vertical overburden (m)	98	112	355
Muon Flux (Hz/m^2)	1.16	0.73	0.041
Muon Mean Energy (GeV)	55	60	138

Backgrounds in Dayabay

- **Our signal - inverse β-decay reaction in the target region of the ADs.**

$$\overline{\nu}_e + p \rightarrow e^+ + n$$

by detecting both prompt positron and delayed neutron captures.

n+ Gd $\rightarrow$ Gd* $\rightarrow$ Gd + γ's(8 MeV) (τ~30μs)

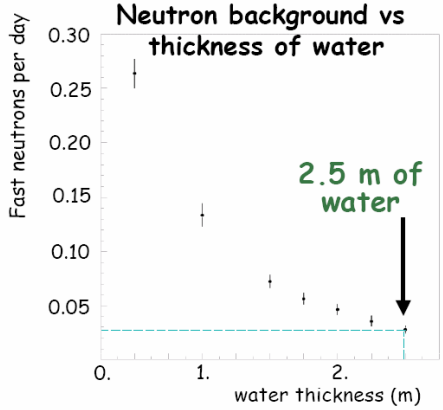
n + p $\rightarrow$ D + γ(2.2 MeV) (τ~180μs)

- **Three major backgrounds in Dayabay, two induced from cosmic-ray muons.**

  - **Cosmic-ray induced.**
    - **9Li/8He isotopes –β-neutron decay.**

      9Li → e- + ne + 9Be* → 8Be +n ($\tau_{1/2}$= 178 ms)
    - **Fast neutrons – prompt recoil proton followed by neutron capture**

The neutron background drops fast with water shield



- **Accidental coincidences, such as from radioactivity.**

Expected Backgrounds

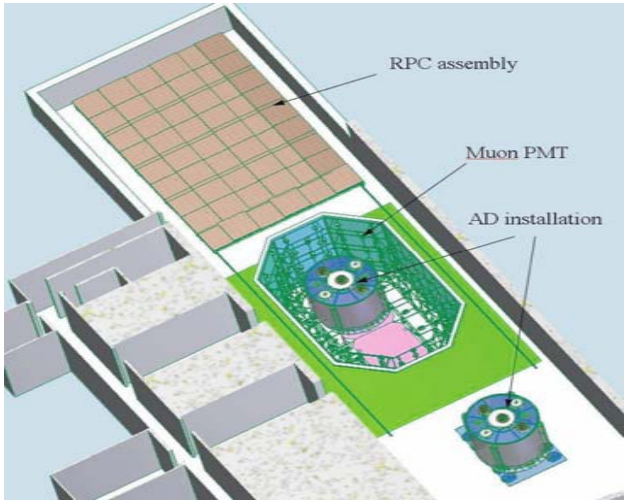
- **The muon system has an instrumented water shield and tracker (99.5%) .**
- **The 2.5m water shield against radioactivity and neutron background from the surrounding rock.**

	DYB site	LA site	far site
Antineutrino rate (/day/module)	840	740	90
Natural radiation (Hz)	<50	<50	<50
Single neutron (/day/module)	18	12	1.5
β-emission isotopes (/day/module)	210	141	14.6
Accidental/Signal	$<0.2\%$	$<0.2\%$	$<0.1\%$
Fast neutron/Signal	0.1%	0.1%	0.1%
^{8}He^{9}Li/Signal	0.3%	0.2%	0.2%

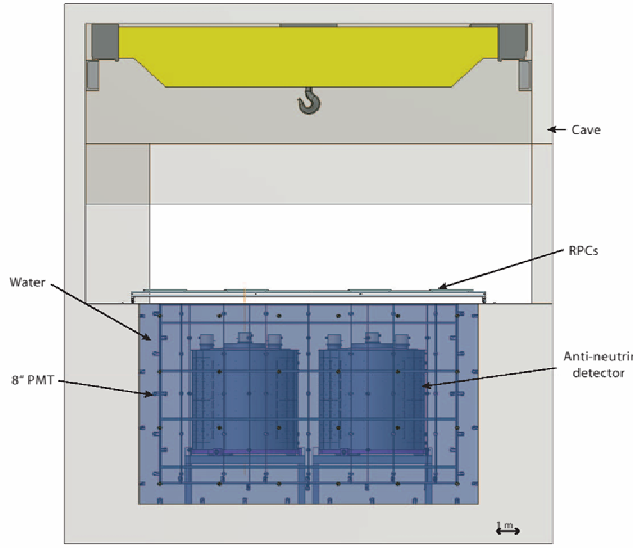
Summary of signal and background rates from simulation.

DayaBay Muon System

- Key requirements for muon system:
  - Shielding thickness - at least 2.5m of water, to reduce radioactivity backgrounds from rock walls.
  - High detection efficiency of muons: > 99.5%. to reduce the fast neutron background from muon interaction in the water and ADs. We must know this efficiency well to control systematic uncertainty.
- Overview of the muon system in the experimental hall.



Muon system in Experimental Hall



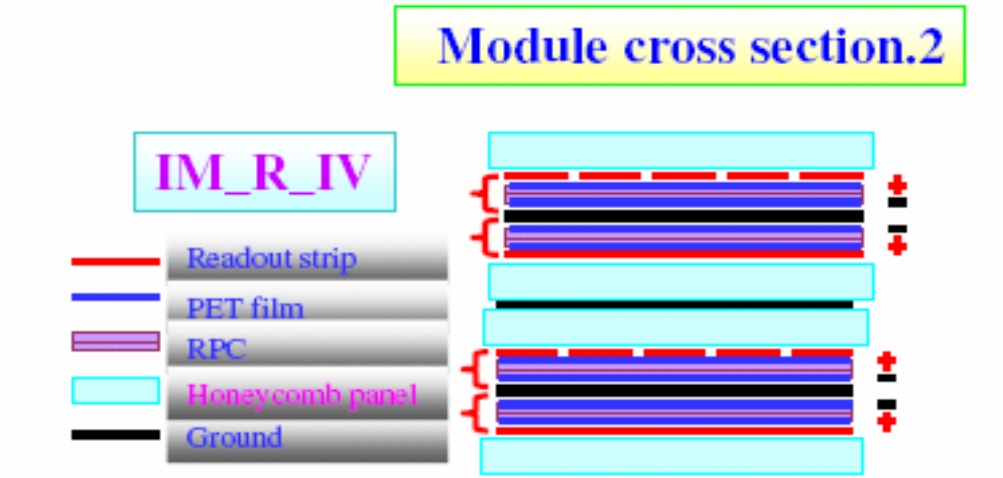
RPC

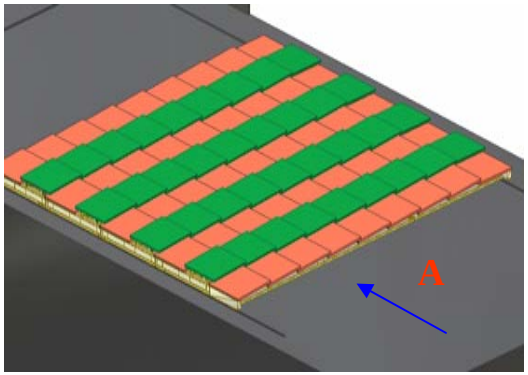
Water Pool

Side View

RPC system

Four Layers RPC Structure
Thickness:
RPC 6mm, PET 0.15mm
Honeycomb panel 1~2cm





3-D top view model

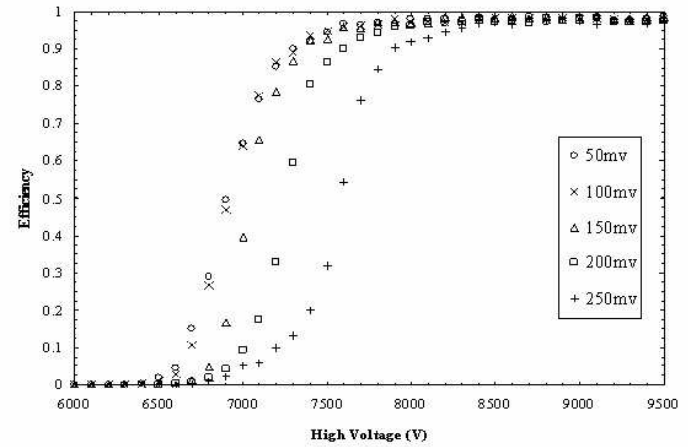
X-strips and Y-strips alternatively placed.

RPC Coverage Area:18m*12m(near), 18m*18m (far).

Total: 756 2m × 2m chambers in 189 modules,
6048 25cm-wide zig-zag readout strips

The spatial resolution ~0.5m.

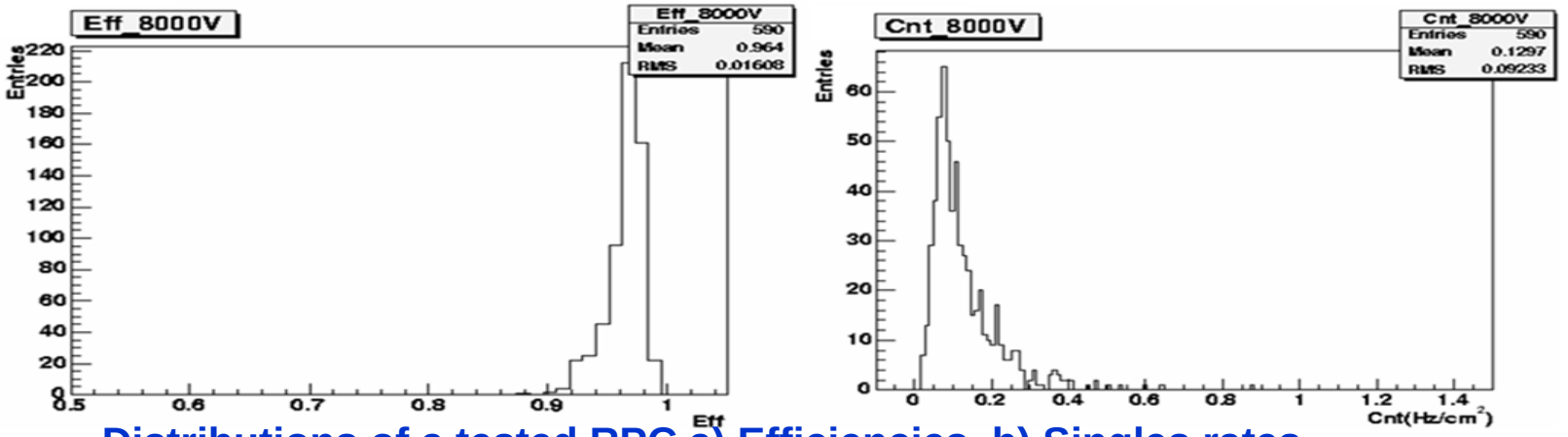
RPC Efficiency



Efficiency of the BES-III RPC versus high voltage for different thresholds.

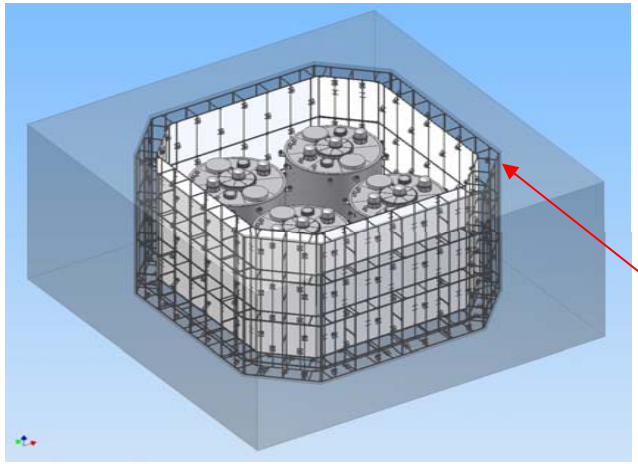
Efficiency for single layer is ~95%.

Efficiency for a trigger in 3 out of 4 layers is 98.6%.



Distributions of a tested RPC a) Efficiencies. b) Singles rates.

Water Pool

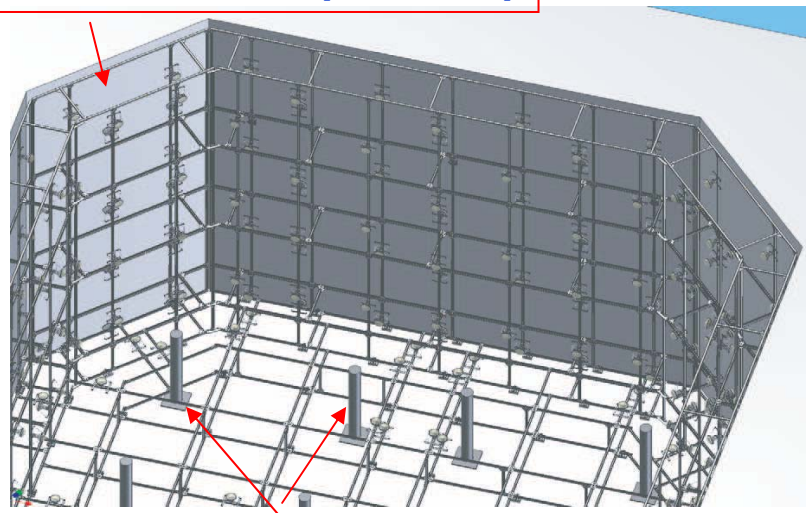


Fall Hall Muon waterpool with ADs

- Muon water pool (10m deep) are divided into inner and outer water shield, each provides independent triggers:
  - 0.8% areal coverage with 962 8” PMTs in total.
- Separated by reflective Tyvek shield.
  - Increase the light yield in the water pool (~3 times).
  - Prevent cross talks between inner and outer.

Outer water shield (1m thick)

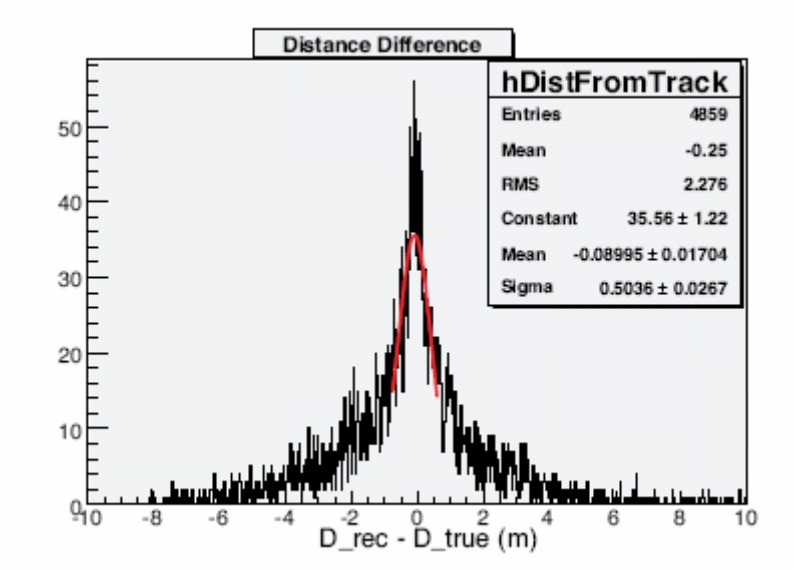
Section of pool with PMT support frames (Without Tyvek)



AD support Legs

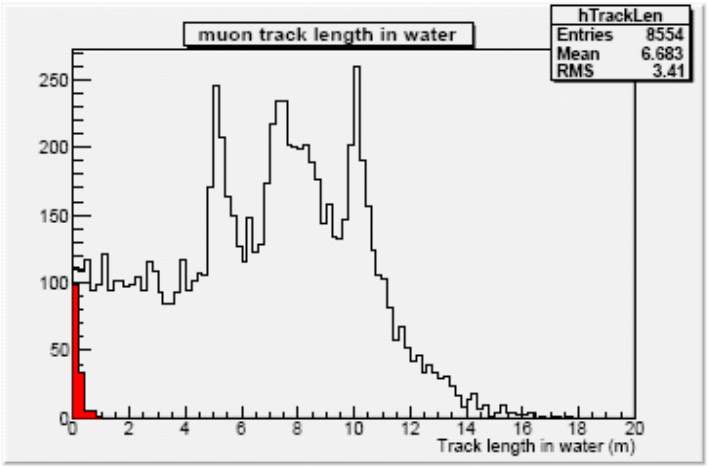
Two water shields combined to give a muon efficiency ~98%, from multiple triggers with #PMT cuts.

Water Pool Simulation Results

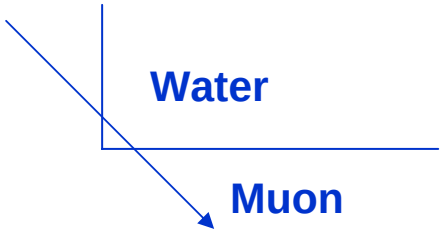


Spatial resolution ~0.5m, reconstructing from time and charge information of the Cherenkov light.

The resolution depends on the #optical photons detected.



Muon Track Length in Dayabay water, Red are from untagged muons, Mostly--Corner-clippers.



Conclusions

- The Muon system are important for reducing the radioactive and cosmic-ray induced backgrounds.

- DayaBay water Cherenkov counters and RPCs combined gives >99.5% efficiency for detecting muons as required.